# GEWEX CONTINENTAL SCALE INTERNATIONAL PROJECT (GCIP)

ABSTRACTS
FOR NOVEMBER 5, 1997 POSTER SESSION

## A PARAMETERIZATION OF MESOSCALE MOIST PROCESSES INDUCED BY LAND HETEROGENEITIES IN GCMS

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ABSTRACT

Heat and momemtum fluxes associated with mesoscale circulations have a significant impact on clouds and precipitation and, as a result, on the hydrologic cycle, the climate, and the weather. However, these processes are not represented in large-scale atmospheric models (e.g., GCMs), which have a low grid-scale resolution and no appropriate parameterization. This considerably affects their ability to provide reliable predictions/scenarios at the seasonal to interannual time scale, which is a major objective for GCIP. In this project, similarity theory concepts are used to develop a parameterization of convective clouds and precipitation associated with mesoscale fluxes and turbulence for large-scale atmospheric models. It is based on the preliminary parameterization of mesoscale fluxes proposed by Lynn and Avissar (1995), which uses a fourth-order Chebyshev polynomial to describe these fluxes. This new scheme provides not only the mean precipitation, but also the higher statistical moments (\ie variance, skewness, and kurtosis) at the grid scale of the GCMs. While these higher moments are currently not being used in any model, Avissar (1997) discussed the needs for this information for the next generation of Soil-Vegetation Transfer (SVAT) schemes. The numerous three-dimensional numerical experiments performed to evaluate this new parameterization (including various characteristic length scales of heterogeneity, soil moisture contrasts, humidity profiles, and background winds) suggest that it is quite robust. However, it needs to be evaluated with real observations. As part of a continuing project, we propose to use the data sets collected in the GCIP LSAs during ESOP-95, ESOP-96, and ESOP-98 for this purpose.

## FIELD-SCALE HYDROMETEOROLOGY DURING SPRING SNOWMELT

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ABSTRACT

A primary goal of the GCIP program is improved scientific understanding and modeling of the coupling between surface and atmosphere. More specifically, the 1997 enhanced observation program has been designated to target land-surface interactions in the Upper Mississippi Basin during winter and early spring, when snowmelt initiates a change from weak to strong surface forcing. Latent and sensible heat fluxes, snowmelt, runoff, and associated changes in soil moisture, temperature, and ice content are crucial surface and subsurface processes that must be modeled. Potentially applicable models exist, but in many cases they have not been rigorously tested, primarily because comprehensive overwinter data sets of all relevant variables, both soil and atmospheric, are rare.

We will collect the data necessary to operate and test available models of these processes at three sites in Minnesota where there are ongoing related research projects. Instrumentation has been installed to allow collection of all soil and meteorological input variables required for PILPS style model intercomparisons, and also to collect the soil temperature and water content data necessary for model output comparison. Measurements of latent and sensible heat flux will be made continuously at one of the sites (Rosemount), and a portable flux measurement system will be employed for short-term flux measurements at the other two sites. All data will be organized and made available to other GCIP researchers.

While we collect the data necessary for model intercomparisons, we will particularly concentrate our own analysis on processes related to the disappearance of snow: evaporation, melt, and most importantly the ponding and subsequent infiltration of meltwater.

## MAPS - 1-H ASSIMILATED GRIDS FOR GCIP AND ASSOCIATED RESEARCH

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ABSTRACT

MAPS, a mesoscale high-frequency data assimilation system and prediction model, is one of the three modeling systems providing assimilated grids for GCIP. MAPS (Mesoscale Analysis and Prediction System) was developed at NOAA/Forecast Systems Laboratory but is also run operationally at NCEP as the Rapid Update Cycle (RUC). The version of MAPS run for GCIP is an advanced, experimental version.

- MAPS is being run currently on a 40-km grid with 40 vertical isentropic-sigma levels. The physics includes:
- MM5 cloud microphysics with explicit prediction of cloud water, rain water, snow, ice, graupel and ice particle number concentration
- soil-vegetation/snow model with 6 soil levels (Smirnova)
- Burk-Thompson turbulence parameterization (Mellor-Yamada level 3.0, with explicit prediction of turbulence kinetic energy)
- MM5 atmospheric radiation, with sensitivity to different kinds of hydrometeors

The use of the isentropic-sigma coordinate has been found to be very beneficial in that it provides extra resolution near fronts and the tropopause and gives improved moisture transport.

Data are being ingested into MAPS now on a 1-h assimilation cycle. These data include rawinsonde, profiler (both 404 MHz and 915 MHz, winds and RASS temperatures), aircraft (winds and temperatures), surface (all variables), VAD winds from WSR-88D radars, and GOES precipitable water values. Soil moisture and temperature has been cycled in an ongoing MAPS assimilation cycle since April 1996, leading to fairly reasonable estimates at present time, particularly compared to climatology. Forecasts are run from MAPS out to 12 h every 3 h, but all fields are continuously cycled, leading to a long-range integration with externally specified lateral boundary conditions and internal correction of atmospheric fields by available observations on an hourly basis.

An active research component in the MAPS project associated with GCIP has been conducted towards improvement of the soil/vegetation/snow model that runs in MAPS. The MAPS soil/vegetation/snow model has been run in 1-d tests for FIFE, O'Neill (Nebraska - 1954), Valdai, and other Russian stations for the PILPS 2D intercomparison with very good results. Results of the 1-d tests of the MAPS soil component and a full description of the MAPS model will be presented.

More information on MAPS, including displays of real-time atmospheric fields and soil moisture in the top 2 cm, can be found at: http://maps.fsl.noaa.gov and http://maps.fsl.noaa.gov/MAPS.40km.html

Information on the MORDS and MOLTS data available for GCIP is available under the latter WWW location toward the bottom.

# REGIONAL MODEL ESTIMATES OF ENERGY BALANCES FOR GCIP

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ABSTRACT

A central interest of the GEWEX Continental-Scale International Project (GCIP) is to estimate the energy balances for the Mississippi River basin at different spatial and time scales. In this poster, regional energy balances from NCEP's Eta model products will be presented. The surface energy balance has been computed for the summer of 1997 using 12-36 hour forecast fields. A comparison with observations in the ARM region indicates that while model estimates depict somewhat higher values (about 20%), there is overall agreement in the magnitudes and ratios among terms. Largest losses of sensible heat from the surface are observed in the western part of the US, while largest losses of latent heat are located over the eastern portion, in agreement with previous studies. Latent and sensible heat estimates for the atmosphere were computed from eight/day EDAS (Eta Data Assimilation System) analyses. These analyses are able to resolve satisfactorily the diurnal cycle that highly impacts the estimates, particularly in the lower troposphere.

**ASSESSMENT OF THREE REGIONAL MODELS FOR GCIP: PRELIMINARY RESULTS FOR AUGUST 1997.**

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ABSTRACT

Products of land/surface parameterizations of three regional models are examined in support of GCIP's need of regional data sets. The models are: (a) the Eta model from the National Centers for Environmental Prediction, (b) the Mesoscale Analysis and Prediction System (MAPS) from the Forecast Systems Laboratory and (c) the Global Environmental Multiscale (GEM) model from the Canadian Meteorological Centre. This diagnostic study is expected to help the developers evaluate the models physical packages. Two three-day samples taken in 1996 and early 1997 allowed us to identify and eliminate, or at least reduce, potential problems when longer term studies are performed. From this early analysis, it became evident that there are unavoidable differences in the way products are stored and distributed, mostly due to requirements of the operational centers generating the data. Still, there has been much progress toward common parameters, formats, and (output) resolutions. Currently, we are examining the surface energy balances, as well as other surface parameters, for August 1997. This is part of a preliminary assessment that will be discussed in the meeting.

# SURFACE ENERGY AND WATER BALANCE FOR THE ARKANSAS-RED RIVER BASIN FROM THE ECMWF REANALYSIS

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ABSTRACT

Average surface energy and water budgets, sub-surface variables and atmospheric profiles were computed on-line with an hourly time-scale from the ECMWF reanalysis for the Arkansas Red river sub-basin of the Mississippi river from 1985-1993. The results for the Arkansas Red River basin are discussed on diurnal, seasonal and interannual time-scales for 1985-1988, and compared with the observed basin scale precipitation and stream flow. The model has a significant spinup of about 25% in precipitation from the analysis cycle to 12-24 hr forecast. The 12-24hr precipitation is about 15% above that observed by hourly raingauges (which probably have a 10% low bias). The model runoff, which is all deep runoff from the base layer, is low by a factor of two, when compared to observed streamflow on an annual basis. The nudging of soilwater in the analysis cycle, based on errors in low level humidity, plays a significant role in the model liquid hydrology. It prevents the downward interannual drift of soil moisture, associated with a shortfall of precipitation in the analysis cycle, while allowing realistic interannual variations of soilwater. It also constrains evaporation in the model, which appears to be accurate on an annual basis to better than 10%. The model coupling of soilwater to evaporation and the low level thermodynamics is similar to observations. The model diurnal cycle of precipitation is in error, with a near noon maximum, while that observed is late afternoon and evening. This diurnal error is probably related to the model error in the diurnal cycle of mixing ratio and boundary layer depth, although the model convection scheme might be involved as well.

# SPATIAL MODELING AND ESTIMATION OF SNOW WATER EQUIVALENT IN THE UPPER MISSISSIPPI RIVER BASIN USING GROUND-BASED, AIRBORNE, AND SATELLITE SNOW DATA

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ABSTRACT

In the second phase of the GCIP research being conducted in the Upper Mississippi basin, the objective is to incorporate all available snow water equivalent (SWE) data (ground-based and airborne) and satellite areal extent of snow cover data into a gridded snow water equivalent product. In this research, we have modified existing spatial interpolation methodologies so that we can use the available ground-based and airborne SWE data and the satellite areal extent of snow cover data to characterize the spatial distribution of SWE and obtain optimal, gridded SWE estimates in the Upper Mississippi River basin. We have developed and tested the models using ground-based, (e.g., cooperative observer data), airborne, and satellite snow data collected over North and South Dakota, Minnesota, Wisconsin, Iowa, and Michigan between March 3 and March 6, 1996. The satellite areal extent of snow cover was derived from GOES satellite images. Using these data and the spatial models, we obtained optimal gridded predictions of SWE and the associated estimates of the root mean square prediction errors over a 5 minute by 5 minute grid covering Minnesota and part of Wisconsin. Maps of the snow water equivalent predictions and of the error estimates were generated using ARC/INFO. These maps enable us to view the spatial distribution of snow water equivalent predictions and the corresponding spatial distribution of the error estimates. Comparisons were made to assess the effects of incorporating the satellite data. Our results enable researchers to examine the spatial distribution of the snow water equivalent and more importantly, eventually, will aid flood forecasting and water resource management efforts.

**MODELING THE AFFECTS OF FROZEN SOILS IN THE GCIP LSA-NC**

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ABSTRACT

The second Large Scale Area (LSA) in the GEWEX Continental-Scale International Project (GCIP) is the Upper Mississippi River basin, also known as LSA-NC. Distinguishing features of LSA-NC are the dominance of a north-south gradient in the mean temperature, the absence of strong precipitation gradients, a semi-humid climate, and the importance of cold season processes, including snow and frozen soils. Frozen soils have until recently, been ignored by most land surface macroscale models, but they can play an important role in increasing runoff during snow melt events.

The three-layer Variable Infiltration Capacity Model, VIC-3L, is a macroscale water and energy balance model. To improve its performance in cold regions, improvements have been made in the snow accumulation model and melt parameterization, and routines to simulate the affects of frozen soils have been added. The improved model has been tested in three stages prior to its application to the entire LSA-NC. In stage 1, the model was run in point mode at the University of Minnesota Rosemount Agricultural Experiment Station, just south of St. Paul, MN. Soil moisture and temperature profiles as well as meteorological data were available fromthe station from December 1994 to March 1996, allowing the model to be calibrated and verified for two winters. Stage 2 used hourly meteorological data from the Minneapolis International Airport weather station to simulate long-term (24 year) conditions at Rosemount in order to evaluate the model's sensitivity to various parameters. Spatial testing commenced in Stage 3 when the model was applied to the Root River, a 1593 km^2 gauged basin in southeastern Minnesota.

The point model results showed that the improved VIC-3L predicts reasonable freezing and thawing depths, but the soil remains frozen longer than indicated by the observations. Extended duration runs showed that frost penetration was most sensitive to soil moisture, and ice content, and that reasonable results could be achieved using measured soil properties. Model runs also indicated realistic increases in runoff during winter snowmelt periods under frozen soil conditions.

# INTERACTIONS BETWEEN BOUNDARY LAYER DEVELOPMENT AND REGIONAL-SCALE SURFACE-ATMOSPHERE EXCHANGES.

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ABSTRACT

Understanding the exchange of heat, radiation and moisture at the land-atmosphere interface is fundamental to understanding weather, climate, and hydrology. These surface exchanges directly modify and in turn are modulated by the atmospheric boundary layer. The meteorological conditions in the surface layer (wind, humidity, temperature) are principal factors in determining the rates of sensible and latent heat exchange between the surface and atmosphere. Surface-layer conditions, however, evolve in response to both surface-atmosphere fluxes and entrainment at the planetary boundary layer (PBL) top. Boundary-layer cloud cover also strongly modulates surface-atmosphere exchange by shading the surface and influencing entrainment rates.

During spring thaw in particular, the sharp contrast between the albedo of snow-covered and bare surfaces (whether forest, grass or soil) should result in the rapid development of abrupt spatial and temporal gradients in the surface energy budget and vertical buoyant mixing. It is possible for instance, that given similar radiative and synoptic forcing, a snow-covered surface would lead to no convective turbulence, and a shallow, moist pbl driven by mechanical mixing, while a dark, bare surface would heat up enough to drive convective mixing. As the winter troposphere is often quite dry, the entrainment of dry air resulting from deep convective turbulence might result in decreasing water vapor mixing ratios at the surface. This might form a positive feedback as evaporation rates would then increase due to the drier surface-layer.

We will study such surface-PBL coupling via colocating PBL profiling observations with flux towers at various locations within the north-central Mississippi River Basin. These PBL observations would be conducted in cooperation with "Field-Scale Hydrometeorology During Spring Snowmelt: Model Evaluation and Improvement Through Comprehensive Measurement," J.M. Baker, USDA-ARS, K.J. Davis, and J.C. Bell, University of Minnesota (NOAA/GCIP).

Three of the flux tower sites are located in the agricultural regions of southern Minnesota, and one is in a heavily forested region of northern Wisconsin. Radiosonde observations will be collected at the three Minnesota sites with support from NOAA/GCIP. Observations will focus on the winter and time of snowmelt. One site is in a heavily forested region of northern Wisconsin, and provides flux measurements at 30, 122 and 396m above ground. We can thus directly observe flux divergence, and with PBL soundings, compute the entrainment rate as well as surface fluxes. PBL profiling via

radar should be available at this site during snowmelt as a result of a DOE/TECO investigation, "Regional Forest-ABL Coupling: Influence on CO2 and Climate," K.J. Davis, U. Minnesota, A.S. Denning, U.C. Santa Barbara, and D.D. Baldocchi, NOAA/ATDD. Flux measurements at that site are supported by "Regional atmosphere/forest exchange and concentrations of carbon dioxide," P.S. Bakwin, NOAA/CMDL and K.J. Davis, U. Minnesota (DOE/NIGEC).

PBL profiling will commence early in 1998.

**PROGRESS OF PROJECT FOR INTERCOMPARISON OF LAND-SURFACE PARAMETERIZATION SCHEMES**

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ABSTRACT

PILPS (the Project for Intercomparison of Land-surface Parameterization Schemes) was established by WMO (World Meteorological Organization) under the joint auspices of GEWEX (Global Energy and Water cycle Experiment) & WGNE (Working Group on Numerical Experimentation) in 1992. It was originally planned to be a 5-year project. In common with other "straightforward" intercomparison projects such as AMIP (Atmospheric Model Intercomparison Project) and ISLSCP (International Satellite Land Surface Climatology Project), the task of inter comparing land-surface schemes (LSSs) has proven much more challenging and much more rewarding than was originally anticipated. PILPS has grown in depth and in international participation through the 5 years since its initiation. Around 20-25 schemes are actively involved in each PILPS Phase. There are about 35-40 schemes and scheme-owner groups who receive PILPS information and join specific intercomparison and analysis tasks.

Over the past five years, PILPS has completed a targeted suite of off-line studies. These have comprised three sets of intercomparisons (Phase 1), which used general circulation model (GCM)-derived forcings, and four sets of intercomparisons (Phase 2) using real (observed) meteorological forcings that were collected from Cabauw, Caumont (HAPEX-MOBILHY), Red Arkansas and Valdai. Jointly with AMIP, PILPS has analyzed coupled results from LSSs coupled with their hosted GCMs (Phase 3). PILPS has initiated PILPS 4 to intercompare selected LSSs in one host 3-dimensional model (GCM or regional model). One of the most interesting and disturbing results from prior PILPS research is large differences among schemes' results (about 40 W/m2) and significant discrepancies in the ability to reproduce observed land-surface situations. There is no evidence to suggest that coupling land-surface schemes (LSSs) to their host AGCMs reduces the scatter among them as compared with off-line comparisons. Resolving the sources of variability in LSS behavior is critical to the GCIP goals, and will require continuing effort from the land-surface research community.

While results from other phases have been reported elsewhere, this poster will focus on Phase 2(d)-Valdai experiments and Phase 4(a)-intercomparison of LSSs (currently LSM and BATS) in NCAR CCM3.

**RAIN GAGE COMPARISONS IN CENTRAL OKLAHOMA**

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ABSTRACT

A field experiment is ongoing is which we are determining undercatch in rainfall due to the wind. Among all natural causes of undercatch by a rain gage windspeed has the greatest influence. The field site is located at Norman, OK and currently comprises 9 gages on a 5 m grid, 6 of which are discussed here. A tipping-bucket gage (of the type used in the Oklahoma Mesonet) and a weighing-bucket gage (used by the Agricultural Research Service, USDA) have been installed in pits, their orifices at ground level to minimize wind effects, and one each of similar type with and without an Alter shield have been placed above ground. It is commonly believed that the use of an Alter shield will significantly reduce the effect of wind is on undercatch. The network of gages has been in existence for nearly two years and to date we have collected data from 74 rain events in which accumulations were greater than a few mm.

The accumulated rainfall amounts (around 1365 mm) from the two independent pit gages based on 67 rain events differ by 2.4%, the largest single rain event difference being 2.3 mm. The small difference establishes confidence in using the pit gages, and, in particular, the tipping-bucket gage, to provide reference rainfall amounts. Based on the accumulated rain amount from 27 events we found that the above ground shielded tipping-bucket rain gage was 4.7% less and the above ground unshielded tipping-bucket gage 5.0% less than the pit tipping-bucket gage. We then removed the Alter shield from the shielded gage and based on another 43 rain events the respective undercatches were 4.6% and 4.4%. The conclusion is that the Alter shield did not contribute in any significant way to reducing undercatch due to wind. In the case of the weighing-bucket rain gages the figures for the 27 events were 5.6% for the shielded gage and 7.5% for the unshielded gage. After the Alter shield was removed from the shielded weighing-bucket rain gage the respective figures were 6.5% and 4.6%. Ideally, the last two figures should have been the same. If one is scaled to the other, the conclusion is that the Alter shield for the weighing gages reduced the undercatch by about 50%. It should be noted that the height of the tipping-bucket gage is 0.6 m and the height of the weighing-bucket gage is 1.1 m. There is a large increase in wind speed over this 0.5 m increase in height so that it is entirely possible that the Alter shield has a significant impact for the weighing-bucket gage but not the tipping-bucket gage.

If rain event differences between above ground and pit gage versus pit gage amounts are plotted the results show approximately 5% undercatch for all events for the tipping-bucket gages. A similar analysis for the weighing-bucket gages shows more scatter than tipping-bucket gages and undercatch that is more or less independent of total rain event amount.

The data set we've collected lends itself to other analyses including the frequency distribution of rainfall duration, the preference for precipitation according to time of day, and the frequency of occurrence of storm average rain rate. These will be presented also.

## THE COMMERCIAL AIRCRAFT WATER VAPOR SENSING SYSTEM (WVSS)

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ABSTRACT

The WVSS has been working for 4.5 months on a United Parcel Service aircraft. The FAA has certified the WVSS for B-757 aircraft. Six units have been delivered by Lockheed Martin Corporation (LMC). The government has ordered 60 more, with installation beginning in February 1998.

A promotional video on the WVSS has been prepared by LMC for their use and for use by the FAA and GCIP (the co-funders of this project). The 8.5 minute video will be shown continuously during the poster session.

## NEW DEVELOPMENTS IN RAINFALL DOWNSCALING: TEMPORAL PERSISTENCE AND LARGE-SCALE FORCING PREDICTORS

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ABSTRACT

Following the rainfall downscaling methodology previously developed in our group (Perica and Foufoula-Georgiou, JGR, 1996) and its two-way interactive coupling with a mesoscale model (Zhang and Foufoula-Georgiou, JGR, 1997), new developments have been pursued into two main directions. First, ways of achieving temporal persistence in the rainfall dowscaled values have been explored. The basic idea behind our approach is to explore the spatio-temporal organization of remotely sensed rainfall at spatial scales of a few kms to several hundreds of kms and temporal scales of a few minutes to several days. Since spatial and temporal scales of variation in a storm system are not independent of each other but relate in a way which is particular to the storm generating mechanism, these variations have been analyzed simultaneously and the presence of space-time scale invariant relationships have been sought. Examples of these relationships for several storms are presented and the potential of using these relationships for developing parsimonious space-time rainfall downscaling schemes with temporal presistence are explored. This persistence might be especially important in cases where the downscaled (redistributed) rainfall is used in a coupled land-atmosphere scheme to update soil moisture availability interactively as the storm involves. Second, relations of the scale-invariant statistical parameterization of rainfall to large-scale forcings derivable from

radar or satellite observations have been investigated. In particular, the volume-averaged cloud liquid water content was considered to represent the large-scale forcing of the rain system and was derived from 3D reflectivity data. Then the temporal variations of the scale-invariant parameters and the cloud averaged liquid water content were examined and predictive relationships between the two were established. Such relationships are expected to be useful in cases where representative values of the Convective Available Potential Energy (CAPE) of the prestorm environment, which is currently used in our downscaling scheme, might be difficult to estimate or not meaningfully defined.

**THE USWRP AND RESEARCH IN QUANTITATIVE PRECIPITATION FORECASTING**

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ABSTRACT

The objective of the US Weather Research Program (USWRP) is to focus and coordinate research, across agencies, to improve operational high impact weather prediction. The lead agency in this program is NOAA. The other participating agencies are the Office of Naval Research (ONR) and the Naval Research Laboratory, the National Science Foundation (NSF), and the National Aeronautics and Space Administration. The participating line offices in NOAA are the Office of Oceanic and Atmospheric Research (OAR), the National Weather Service, and the National Environmental Satellite, Data and Information Service. The USWRP performs its function by focusing research resources within and across agencies by adding small amounts of funding, but principally by reprogramming resources within agencies. One of the major mechanisms used to focus funding is the USWRP/NSF university grants program to which the agencies contribute. Proposals in this grants program are competitively evaluated and awards are distributed to university researchers who are most often partnered with a federal laboratory. Within agencies, competitive research grants are made available, again on a competitive basis with internal agency funding. These grants conform to the scientific themes of the USWRP. Examples of this process are the Severe Weather Program Initiative which has been established for several years and the soon-to-be established Predictability Initiative of ONR.

The USWRP-directed research focuses on three topics:

- Data assimilation/mix of observations
- Quantitative precipitation forecasting (QPF)
- Tropical cyclones with emphasis of hurricanes at landfall

The second topic is most relevant to GCIP, although these topics are not mutually exclusive. It is clear that the first topic can be important to QPF research and the last topic could benefit from such research. Within the USWRP, QPF includes the estimation and depiction of water vapor distribution, radar and satellite estimation of precipitation amount and type, mechanisms for forcing, initiation and dissipation of convection, orographic precipitation, both stable and convective, improved physics, including microphysics, vegetation, soil effects, and explicit representation of convection in forecast models, predictability, the value of ensemble forecasting at the mesoscale, very short-term forecasting techniques that combine recent observations and models, and techniques to verify mesoscale prediction of precipitation. Examples of USWRP supported research in the QPF area are presented. They include ensemble forecasting to

obtain probablistic QPF and research in polarimetric radar to determine precipitation type and improve estimates of precipitation amount.

# BENEFITS TO OPERATIONAL WATER RESOURCES MANAGEMENT DUE TO THE UTILIZATION OF MONTHLY CLIMATE MODEL FORECASTS: DES MOINES RIVER - SAYLORVILLE RESERVOIR

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ABSTRACT

The 3-year research program aims at providing a quantitative answer to the question: What is the economic and environmental benefit that Global Climate Model (GCM) forecasts offer to the operational management of reservoirs controlling regional water resources? Mathematical models and simulation studies are used with actual data from large multi-purpose reservoir hydrosystems. The research project is a multi-disciplinary one that brings together three groups with expertise in climate forecasting (SIO-UCSD), hydrologic forecasting (HRC), and operational reservoir management (GIT). The results of this work are expected to be of importance both for the climate community and the user groups, as they will clearly show the need for interaction and will define optimal interaction strategies. The present case study focuses on the Saylorville Reservoir on the Des Moines River in Iowa. The plant, operated by the U.S. Army Corps of Engineers, has flood control and water quality objectives, while, as part of this study, the feasibility of hydroelectric power production is examined. The methodology applies state-of-the-art integrated forecast-control methods with and without GCM information, and compares the results in terms of measurable economic and environmental benefits. The well-validated Max Plank Institute for Meteorology Atmospheric GCM is used to provide climate forecasts for up to 3 months starting on the first day of each month of record with a 2.5-degree horizontal and monthly temporal resolution. A macro-scale hydrologic model (an adaptation of the operational National Weather Service streamflow forecast model, with 1,000-3,000 km2 resolution) complemented by a detailed hydraulic routing model of the Muskingam-Cunge type, is used in an ensemble forecasting methodology to generate reservoir inflow forecasts for 4 months into the future with daily resolution. A decision support system generates trade-offs among various system objectives over several decision horizons and, given a certain control strategy, determined in

collaboration with the appropriate User group, operates the reservoir and generates regional benefits. Unique aspects of the methodology are: (a) makes possible, for the first time, a quantitative answer to the question posed for reservoir systems, allowing for the best performance of the management system both with and without the benefit of GCM forecasts; (b) couples a forecast with a decision-support system with explicit account for forecast uncertainty; and (c) brings together the climate forecast community with the user community. Results to date show: (a) successful operation of the forecast-control models over a variety of hydrologic regimes over a 20-year period with benefits for flood control, low-flow augmentation, and hydroelectric power production; (b) that the GCM information can be useful primarily for wet years for the study region; and (c) that the utilization of forecast uncertainty is important for improved reservoir management.

**EMPIRICAL AND IDEALIZED STUDIES OF HEAVILY PRECIPITATING STORMS: THEIR STRUCTURE AND ROLE IN ESTABLISHING THE VERTICAL DISTRIBUTION OF WATER VAPOR IN THE TROPOSPHERE**

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ABSTRACT

An outstanding problem in studies of the global hydrological cycle is to understand how the storms producing large amounts of precipitation on the ground establish the large-scale vertical distribution of water vapor and persistent, climatologically significant cloud layers. A major problem in quantitative precipitation forecasting is to verify whether models are producing the right amounts of precipitation over the right areas for the right reasons. Traditional methods of verifying only by surface precipitation amount and locations are not unique indicators of the physics producing the precipitation.

This research addresses both of these problems--how storms establish the vertical distribution of water vapor and how better to verify the precipitation physics of forecast models- by seeking objective measures of storm structure and investigating the predictability of environmental water vapor budgets in relation to the factors determining storm structure. We are conducting two studies:

An empirical study of the three-dimensional WSR-88D data from heavy rain events in the Kansas-Oklahoma-Texas region is investigating methods of statistically characterizing storm structure observed by radar. Despite producing similarly large amounts of rain over the area covered by a radar, these storms often had different physical causes reflected in different horizontal and vertical structure. We differentiate among these storm types by analyzing the spatial distributions of radar reflectivity.

Horizontal structure of the radar echo field is characterized by plotting histograms of the area-wide rainfall amount as a function of radar-echo intensity and by identifying patterns of mesoscaleorganization implied by objectively analyzed convective and stratiform precipitation regions.

Vertical structure is characterized by compiling the joint probability distribution of radar-echo intensity and altitude. This plot may be instantaneous or cumulative over time, and it may be subdivided into convective and stratiform components.

These products, calculated for a whole storm by combining the WSR-88D data for several sites and/or times, are strong indicators of the types of physical mechanisms at work in producing heavy rainfall and characterize the storms more uniquely than do surface precipitation amounts and locations.

An idealized study will use a high-resolution three-dimensional numerical model (ARPS) with full ice-phase microphysics to examine generic heavy precipitation events. The model output will be analyzed to determine how the heavily precipitating convection establishes the water vapor distribution and produces long lasting cloud layers in its environment--especially in the upper troposphere. This study uses a three-dimensional model in order to represent the horizontal transport processes accurately. Turbulent entrainment and cloud-internal vorticity fields are crucial to these processes and are not adequately represented in one-dimensional or two-dimensional cloud models. The aim is to determine how heavy precipitation storm prototypes affect the moisture field and to determine how small variations in storm structure affect the way a storm prototype distributes moisture.

Ultimately the empirical and idealized studies will work together. The empirical study will provide methods for using WSR-88D data to characterize storm structure in physically unique ways. This characterization will provide a basis for using WSR-88D data to verify whether models forecast the right precipitation in the right place for the right reason. Such verifications, in combination with our idealized study, will allow us to use models to determine the role of storm structure in establishing the vertical distribution of water vapor in the troposphere.

# HETEOROGENEITY OF LAND SURFACE PROPERTIES DURING SNOWMELT EPISODES

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ABSTRACT

The changes in albedo during a snowmelt episode dramatically alter the surface energy budget. Numerical weather prediction models use simplified representations of this process, typically parameterizing the albedo as a function of fractional snow cover, which in turn is represented as a function of snow depth or snow water equivalent. The goal of this project is the collection and analysis of a data set that will promote development of snow parameterizations that will accurately simulate the change in albedo during snowmelt episodes. The site of the measurements is the rather flat prairie landscape of east-central Illinois, which can develop high spatial heterogeneity of snow cover during wind-blown snowfall events. Measurements will include (1) albedo and snow cover fraction along a 50-100 km transect, using a helicopter-born instrument package; (2) albedo and snow cover fraction as a function of scale, obtained by vertical helicopter flights; (3) ground-based snow depth and snow water equivalent along 10 or more snow courses along the transect; (4) surface energy budget observations at 2 sites along the transect. The ephemeral nature of snowpack at this site will provide a potential opportunity to measure several snowmelt episodes during a single winter.

**EVOLUTION AND TESTING OF GCIP MACROSCALE HYDROLOGICAL MODELS: APPLICATIONS TO GCIP LSA-NC AND LSA-E**

Dennis P. Lettenmaiera, Keith Cherkauera, Greg O'Donnella, Ralph Dubayahb, and Eric F. Woodc

ABSTRACT One of the major modeling activities supported by GCIP has been the development and testing of macroscale hydrological models, capable of simulating streamflow for continental scale river basins, such as major tributaries of the Mississippi. One such model is the two-layer Variable Infiltration Capacity model (VIC-2L), which simulates runoff over a rectangular grid mesh (typically of size _ to one degree latitude longitude), and routes the flow through a link-node approximation of the channel network to the channel outlet. This scheme, which has been applied successfully to several major continental rivers including the Columbia, Missouri, Ohio, Arkansas-Red, and Upper Mississippi, among others. It has evolved from a single soil layer with a simple "beta function" type evaporation scheme, into a two (or three) layer soil model, with biophysically based evapotranspiration, full energy balance computation, parameterization of rainfall spatial variability, and a physically based snow and frozen soil algorithm coupled to an improved, physically realistic ground heat flux scheme.

Recent applications of the revised version of the model with improved parameterizations are illustrated for two of the GCIP Large-scale Study Areas (LSAs): the Upper Mississippi (LSA-NC), and the Ohio (LSA-E). The Upper Mississippi is of particular interest because of the importance of cold season processes, especially thin snowpacks and frozen soils, which can have pronounced effects on runoff production as well as the surface energy balance. Other distinguishing features of LSA-NC are the dominance of a north-south gradient in the mean temperature, the absence of strong precipitation gradients, and a semi-humid climate. An important aspect of the Ohio River application is testing of the feasibility of estimating some model forcings using remotely sensed data. Macroscale hydrological model applications to continental-scale rivers are inevitably hindered by the scarcity of land surface observations used both for model parameterization and forcing. Remote sensing provides a potentially attractive alternative to the use of ground observations, given the recent availability of consistent, long-term satellite records, advances in remote sensing algorithms, and the employment of new remote sensing instruments. The Ohio River application includes testing for a single calendar year, using first station data, and then using remotely sensed estimates of air temperature, as well as incoming solar radiation, and vapor pressure deficit (VPD). The one year of comparison (dictated by the availability of remotely sensed forcings) was embedded within a longer 10-year simulation period for which an extensive station data network facilitated comparisons. The similarity of the model provides an encouraging indication of the potential for future use of remotely sensed meteorological data in regions of scarce data.

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**PARAMETERIZING SUBGRID-SCALE SNOW-COVER HETEROGENEITIES FOR USE IN REGIONAL AND GLOBAL CLIMATE MODELS**

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ABSTRACT

To improve the depiction of winter-land-atmosphere interactions and feedbacks within regional and global climate models, we are developing a snow-cover submodel that explicitly includes the influence of subgrid-scale snow-cover variability. A primary objective of this study is to improve our understanding and ability to describe and model the complex interactions among the atmosphere, snow, and land during winter and spring seasons, within the context of climate models. To accomplish this we have implemented a climate version of the Regional Atmospheric Modeling System (RAMS), developed at Colorado State University, for a domain which includes the Rocky Mountains, Central Grasslands, and Upper Mississippi Basin regions of the United States. The research takes advantage of recent improvements in the model's ability to perform full annual integrations, and makes additions which are designed to improve the model's representation of relevant snow-related processes, such as appropriate energy flux partitioning during the melt of patchy snow covers, and the relationships between melt and subgrid-scale snow distributions. The snow submodel also takes advantage of remotely-sensed snow-cover distribution products produced by the NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC). In addition, the submodel is formulated to assimilate future snow-distribution data sets generated as part of the SNOMAP algorithm being developed to map high-resolution (500 m) daily global snow cover using the Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS). This research is expected to lead to substantial improvements in grid-scale and subgrid scale representations of atmospheric and snow-related processes within regional and global climate models.

**LONG-TERM ENERGY FLUX MEASUREMENTS FOR IMPROVED LAND SURFACE PARAMETERIZATIONS WITHIN THE GCIP DOMAIN**

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ABSTRACT

Continuous measurements of the surface energy balance components (net radiation (), sensible heat flux (), latent heat flux (), ground heat flux (), and heat storage ()) have been initiated at two representative sites in GEWEX/GCIP Large-Scale-Areas LSA-SW (Little Washita Watershed) and LSA-NC( Champaign, Illinois). Latent energy fluxes from the soil and canopy systems for crop landuse types are determined separately to provide a complete data set for (1) the evaluation of the surface layer submodels currently used in synoptic scale and general circulation models, and (2) the determination of the seasonal climatology for both H and LE. For regions characterized by partial canopy cover, which are significant in the GCIP domain, the relative contributions to the total evapotranspiration from plant and soil components can vary significantly. Measurements of additional hydrological components include precipitation and soil moisture. The atmospheric forcing variables include solar and net radiation, air temperature and humidity, wind speed and direction, and soil temperatures. Data from these sites are being used to 1) evaluate the temporal variability of surface fluxes as a function of season; 2) the relative contributions to the total evapotranspiration from soil and vegetative components 3) evaluate the timescale of plant recovery after the onset of water stress and consequent rainfall 4) evaluated the relative importance of the components of the surface energy balance during the cold season, especially the latent heat of fusion. Winter time data from the Champaign, Illinois site have provided some insight into the controlling factors of the surface energy balance. First, changes in air mass temperatures play a significant role in modulating the soil temperatures. Diurnal changes are often observed but these are generally small excursions compared to those observed from changes in air mass temperatures. Another frequent observation is that a significant fraction of the total available energy is consumed in changing frozen precipitation (snow) to liquid water. Rapid increases in H and LE are often observed after frozen precipitation has melted.

## A CONTINENTAL-SCALE SOIL CHARACTERISTICS DATASET FOR CLIMATE, HYDROLOGY, AND ECOSYSTEM MODELING

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ABSTRACT

Over the past several decades environmental models (climate, hydrology, and ecosystem) have begun to include increasingly sophisticated parameterizations of the interaction between the land surface and the atmosphere in so-called soil-vegetation-atmosphere transfer schemes (SVATS). A major component of most SVATS is a detailed description of surface and subsurface water movement which, in turn, requires an understanding of the nature and distribution of soil physical and hydraulic properties over regional to continental scales.

To address the needs of the environmental modeling community we have developed a Conterminous United States Multi-Layer Soil Characteristics data set (CONUS-SOIL) for use in regional to continental-scale applications. The poster will highlight the development of CONUS SOIL, our current efforts to improve the dataset with soil physical and hydraulic characterization data, and our plans for developing a North American Multi-Layer Soil Characteristics data set (NOAM-SOIL).

# RECENT GCIP PROGRESS IN COUPLED LAND-SURFACE MODELING AND DATA ASSIMILATION IN THE NCEP MESOSCALE ETA MODEL

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ABSTRACT

In collaboration with the NWS Office of Hydrology (OH) and the land sciences group of NESDIS, the Environmental Modeling Center (EMC) of NCEP continues to advance several major GCIP-sponsored initiatives to demonstrate the positive impact and hydrometeorological applications of improving land/atmosphere 1) coupled modeling, 2) data assimilation, and 3) GCIP-focused model output/archiving/validation in the NCEP weather and climate modeling suites. This tri-agency GCIP effort among NCEP, OH, and NESDIS is known as the NOAA GCIP Core Project.

This poster presentation will highlight the substantial progress in these initiatives in NCEP's operational mesoscale Eta model. The notable success of these land-surface initiatives in the Eta model has convinced NCEP to next embark on extending these advances to NCEP's global medium-range and global climate models in the next phase of GCIP, to include the imbedding of regional land/atmosphere coupled models in the global ocean/atmosphere coupled climate models.

1. The Eta-based coupled model GCIP progress includes:

    - baseline uncoupled off-line testing in the two-year GEWEX ISLSCP Global Soil Wetness Project (GSWP), and PILPS-2c (Arkansas-Red) and PILPS-2d (Valdai)
    - land-surface modeling refinements arising from evaluation of the first 18 months of operational performance of the new land-surface scheme coupled to the Eta model,
    - the application of a new NESDIS 5-year climatology of NDVI-derived global, monthly, 0.14 degree green vegetation fraction
    - the application of a new NESDIS realtime, daily, 23-km, N. Hemisphere snow cover analysis
    - significant improvement to the surface solar insolation physics of the Eta model
    - improvements to the cloud microphysics and reduction of cloud cover biases in the Eta model

- development and testing of new convective parameterization schemes to reduce Eta model precipitation biases

2. The Eta-based data assimilation GCIP progress includes:

   - the realtime production of the national "Stage IV" hourly 4-km, gage/radar precipitation analysis
   - hourly assimilation of the above Stage IV precipitation analysis into the Eta 4-D Data Assimilation System (EDAS)
   - transition to a fully continuous Eta-based 4-D data assimilation system
   - assimilation of satellite cloud analyses into the Eta model cloud microphysic

3. The Eta-based output/archive/validation GCIP progress includes:

   - output and archiving of an extensive and comprehensive suite of near-surface, surface, and sub-surface fields (including all terms of the surface water and energy budgets) from the Eta data assimilation and forecast system (both 40-km gridded fields and station-oriented hourly time series at about 300 stations
   - coordination of the above output strategy with the two other GCIP regional modeling groups (NOAA/FSL/MAPS and Canada) to adopt a common output grid, data packing, and station lists to facilitate the GCIP-supported 3-way model intercomparison study of H. Berbery
   - directly support the Eta model water budget studies of GCIP-supported PIs: Berbery/Rasmusson, Yarosh/Ropelewski
   - directly support the ground-based Eta model validation work of GCIP-supported PIs: Betts/Chen, Yucel/Shuttleworth, Marshall/Crawford
   - directly support the GOES satellite-based Eta model validation work of GCIP supported PI D. Tarpley

One NCEP/EMC poster will cover areas 1) and 2) above, while a second NCEP/EMC poster, at the request of the GCIP Program Office, will cover area 3). In addition to the above NCEP/EMC posters, we emphasize that separate abstracts/posters will be presented by OH by John Schaake et al. and by NESDIS by Dan Tarpley et al.

The EMC Eta-model GCIP web site address is:
http://nic.fb4.noaa.gov:8000/research/gcip.html

**VALIDATION OF THE STAGE III RADAR RAINFALL PRODUCT OVER OKLAHOMA**

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ABSTRACT

Work has recently been completed which provides error bounds for the hourly 4km x 4km stage III radar rainfall product over the Oklahoma. the results, which are for the summer of 1994, indicate that the product has essential zero bias on the average, but contains a significant amount of random error. In addition, the product tends to severely overestimate high rainfall rates while underestimating low rainfall rates. Thus, while the over bias is near zero there is a strong bias conditional on rainfall rate. Some ancillary results indicate that, on the average, summertime storm conditions over Oklahoma require that 2 raingauges are needed to estimates 16km2 hourly rainfall given a 5% sampling error. These results are for average conditions and include all the errors inherent in radar rainfall estimation (e.g., range effects, calibration error, etc.). The error bounds show conclusively that the results mentioned above are statistically significant at the 95% level. By using a Monte Carlo simulation technique the usual classical statistical assumptions associated with standard intercomparison techniques did not have to be made.

**DIAGNOSING WATER AND ENERGY BUDGETS FOR GCIP FROM MODELS AND OBSERVATIONS**

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ABSTRACT

Model results and observations are used to make detailed analyses of the energy and water budgets for North America (with an emphasis on the central US GCIP region) on interannual time scales. Because the observational network is sparse in time and space (especially the further one goes back in time), climate models, particularly GCMs, become an attractive tool. GCMs provide output on a regular grid and at regular time intervals, and all quantities can be assumed physically consistent (though this does not guarantee accuracy). The primary modeling tool was the new generation NCAR climate model (CSM/CCM3). Model simulations include a 46-year CCM3 run CSM and with SST specified according to data supplied by NMC for the years 1949-1994, standard 'AMIP' runs using observed SST for 1979-1994 (these SST are slightly different than what was used for the 'NMC' case), and a 300 year run with the fully-coupled ocean-atmosphere version of CSM. All runs include the land surface model (LSM) component which computes evapotranspiration and soil water. Our analysis emphasizes time series of key variables (including lagged correlations), and constructing composites of wet and dry years. Particular attention is paid to the warm season (MJJ). Where possible, the model results are compared with reanalyses from NCEP and NASA/DAO, as well all available observational datasets, including GPCP and Xie and Arkin for precipitation, and SRB and ERBE output for surface and atmospheric energy components.

High correlations are readily apparent between soil moisture, temperature, and precipitation in the CCM3/NMC and CCM3/AMIP runs, indicating the strong relationship between these variables for the GCIP warm season. Reasonably high correlations are also obtained from OLR and surface energy fluxes. These correlations suggest the causal mechanisms responsible for anomolously wet or dry years. Also apparent is a roughly decadal low-frequency pattern among these key variables. Interestingly, neither the correlations nor the low-frequency behavior are as apparent in the fully-coupled ocean-atmosphere CSM run as they are in the observed SST runs.

The ability of CCM3 to simulate precipitation accurately was also investigated by comparison both to observations and to results from the earlier version CCM2 at a range of horizontal resolutions. CCM3 at T42 did signifcantly better than CCM2 at T42, due to improved physical paramterizations. The most important improvement was to schemes used for convection, though it is clear that considerable work still must be done on this parameterization. Interestingly, outside of the ITCZ zone, increasing resolution in CCM2

from T42 to T170 showed relatively little improvement in the simulated precipitation. Because of the potential importance of snow cover in accounting for interannual anomalies and model biases in temperarure, we ran a regional climate model over several US domains (including the northern GCIP region) with an improved snow albedo formulation. The regional model was forced both by anaylses and by output from CCM3. This model combination results in a more realistic seasonal cycle of snow cover.

## SENSITIVITY OF DOWNSCALED PRECIPITATION ESTIMATES TO MODEL ASSUMPTIONS

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ABSTRACT

The Utah Limited Area Model (Utah LAM) is integrated for a two week episode characterized by heavy rainfall during the summer 1993 Mississippi River Basin floods. The model is initialized and bounded by conditions provided from NCEP and ECMWF reanalyses in a series of experiments designed to test the sensitivity of precipitation simulations to model assumptions.

All experiments produce heavy rainfall in the north-central Mississippi River Basin, with peak values centered around observed maxima near Iowa. There are substantial differences in simulated rainfall east of Iowa into Ohio, and southwest of Iowa into Oklahoma, where heavy rainfall also occurred. These features display a surprising degree of sensitivity to choice of reanalysis (NCEP or ECMWF) and to the technique used to impose reanalysis information into the Utah LAM domain.

We find that the model precipitation simulations are substantially improved in experiments that directly impose the outer (reanalysis) model guidance directly within the LAM forecast domain. Imposition of internal wavenumber 4 is more effective than imposition of internal wavenumber 2. LAM simulations with .5 degree grid size produce more realistic rainfall distributions than simulations with 1 degree resolution.

Some of the differences of rainfall simulations produced by LAM experiments driven by ECMWF and NCEP products can be attributed to differences of surface evapotranspiration between the two reanalyses, while other differences may reflect inherently low predictability of precipitation and the resulting sensitivity of two week simulations to small differences of initial and boundary conditions.

Such sensitivity is minimized in simulations in which the initial and boundary conditions are selected from time averaged states. Selected preliminary experiments suggest that two week averaged states obtained from the drought year of 1988 and the flood year of 1993 produce LAM precipitation signatures that are qualitatively similar to observed anomalies.

## INACCURACIES AND ADJUSTMENTS OF IN-SITU MEASUREMENTS OF SOLID PRECIPITATION FOR GCIP LAS-NC AREAS

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ABSTRACT

All measurements of solid precipitation by in-situ gages in the GCIP north-central large study area (LSA-NC) have been, and are, substantially less than "true" precipitation (by 20 to 40 percent or more). The major reason for the reduction in catch during snowfall is the result of wind action preventing snowfall from entering the gages. Consequently, the historical and present records of daily and hourly measurements of solid precipitation in the LSA-NC area are very poor for, a) calibrating remote measurements of solid precipitation, b) as input, or evaluation of output from, land-atmospheric climatic models, or c) parameterization of hydrologic models. The GCIP study to produce adjusted historical records and develop recommendations for operational procedures to provide investigators with near-real time records of adjusted solid precipitation measurements are discussed. The study has already provided preliminary long-term average winter (January-February) precipitation values. Maps (isohyetal) of these values provide a knowledge of the distribution of winter precipitation for the north-central GCIP area that has not been previously available.

## HIGH RESOLUTION SHORTWAVE RADIATION BUDGETS FROM GOES 8 IN SUPPORT OF GCIP ACTIVITIES

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ABSTRACT

NOAA/NESDIS is currently producing real time shortwave surface radiation budget parameters, in support of modeling activities, in progress under the GEWEX Continental Scale International Project (GCIP). A modified version of an algorithm, developed at the University of Maryland is being used, to produce the satellite estimates. The model is currently driven with GOES 8 satellite data, as pre-processed at NOAA/NESDIS, and auxiliary information, as available form the Eta model. The output parameters of the model include: surface downwelling and upwelling shortwave global and diffuse fluxes, and similar quantities at the top of the atmosphere. The fluxes are estimated on an hourly basis for 0.5 degree targets for an area bounded by 67-125 W longitude and 25-50 N latitude. Combinations of these fluxes allow computation of such parameters as surface albedo, photosynthetically active radiation, and top of the atmosphere net shortwave fluxes. At the University of Maryland, the operational version of the model is evaluated independently off-line, and model improvements are being developed and tested. At present, Version 2 of the model is being run at NESDIS. Results of what was learned from the validation of Vesion1, needs for the modifications introduced, impact of the

changes on the product during the snow-free season, and issues related to future plans, will be presented.

**RPN / CMC MODEL ARCHIVES AND ACTIVITIES IS SUPPORT OF GEWEX**

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ABSTRACT

This presentation deals with the outputting, archiving and supplying to GCIP researchers the analyses and forecasts from the operational regional model at the Canadian Meteorological Centre (CMC) for calculations of energy and water cycles on a continental scale. The overall goal of many GEWEX research projects is to undertake a detailed study of the water and energy budgets in order to improve our understanding, modelling, and prediction of them. CMC and Recherche en prévision numerique (RPN) hope that we will be able to help provide a measure of operational model representations for many of the relevant fields. This requires an extension of our operational model outputs and archives for use by the researchers participating in these studies. Following a request from GCIP, CMC has undertaken the outputting of analyses and forecasts from the operational regional model. NCEP's ETA model, FSL's MAPS system, and ECMWF outputs are also being supplied, providing data sets from several operational forecast systems for the calcualtion of water and energy cycles on a continental scale. These outputs are being used to complement and compare with intensive observations from a variety of observing platforms in an attempt to produce the best possible water and energy budget analyses. CMC and RPN have welcomed this chance to be invloved in GCIP. We hope that by participating along with colleagues in other operational and research centers, we will be able to provide a measure of the inter-model variability for the model outputs for these projects.

In the presentation in Boulder, the emphasis will be on a sample period in the summer of 1997 for which the modelling centers have agreed to produce comparable model output fields to show GCIP researchers the types of fields that will be available for their studies throughout the GCIP period. We will also illustrate the type of GEWEX research that RPN is conducting by presenting latest results on our study of the uncertainty in GEWEX water and energy budgets arising from uncertainties in the initial conditions produced by our data assimialtion system. In particular, we will demonstrate the impact of a sophisticated land surface scheme in budgets calculated in ensembles of monthly forecasts over the GCIP domain.

**GCIP WATER AND ENERGY BUDGETS**

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ABSTRACT

Some spatial and temporal aspects of water and energy budgets for the GCIP region are provided from the NCEP analysis and reanalysis, reanalysis global spectral model (GSM), and regional spectral model (RSM) budgets. Spatial aspects include summertime horizontal and vertical variations. Temporal aspects include seasonal, decadal, and diurnal variations.

Large-scale spatial variations in the GSM and RSM budgets are clearly related. However, the RSM has much smaller scale variability in precipitation and atmospheric moisture and heat convergence, especially over mountainous regions, where spurious precipitation can be generated.

Vertical GSM variations demonstrate the strong contributions by the sensible and latent heat fluxes near the surface and the strong contributions by the latent heating aloft, which is balanced largely my adiabatic cooling as well as radiative cooling. The residual tendencies are also important contributors to the analysis budgets and indicate potential analysis and model problems near the surface, boundary layer top, and tropopause.

Analysis seasonal variations indicate that during the winter, incoming solar radiation at the surface is balanced by long-wave cooling whereas during the summer, latent and sensible cooling are equally important.

Reanalysis products suggest that the precipitation and soil moisture increased during the period (1973-1997). This increase in soil moisture is not well related to the reanalysis surface evaporation and runoff, which show relatively little change on all time scales. The dominant decadal variability is best represented by moisture convergence, precipitation, and soil moisture tendencies.

Diurnal RSM variations show the strong control by the solar radiation, which is partially balanced by the strong increase in surface evaporation, and sensible heating during the day. These processes become small and compensating during the nighttime. Longwave cooling has little diurnal variation. Consistently, surface temperature decreases almost linearly during the nighttime and then follows the rise and fall of the sun during the day.

# EVALUATING SOIL MOISTURE MODELING

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ABSTRACT

We present here our current collection of in situ soil moisture data from around the world from the Global Soil Moisture Data Bank http://www.meto.umd.edu/~alan/soil_moisture). We currently have data sets at least 6 years long (and most more than 15 years long) from more than 400 stations around the world, and those that have been quality-controlled are available at the web site. We have been using these data for remote sensing, analyses of climate change and model evaluation. Here we present the current status of our efforts at model evaluation, including our AMIP Diagnostics Subproject, PILPS Phase 2(d), and the Global Soil Wetness Project.

In analyzing the AMIP I results, we have found that models with 15-cm field capacities cannot capture the large high latitude values of soil moisture. Several models have large soil moisture trends during the first year or two of the AMIP simulations, with potentially large impacts on global hydrological cycle trends and on other climate elements. This analysis will continue with AMIP II. Our data from the grass-covered catchment at Valdai, Russia, are being used in the PILPS Phase 2(d) project, an 18-year intercomparison with all the PILPS models. The simulations are just now being completed and we will present the first results. Our Russian data sets are an integral part of the verification process for the ISLSCP Global Soil Wetness Project, and we will present evaluations of these simulations compared to observations.

**WATER BUDGET AND INTERCOMPARISON STUDIES FOR THE CENTRAL UNITED STATES**

PART I - OBSERVED WATER BUDGET AND ITS VARIABILITY

PART II - SENSITIVITY OF WATER BUDGET TERMS AND INTERCOMPARISON STUDIES

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Evgeney S. Yarosh
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ABSTRACT

Two poster presentations will give an overview of the work on water budget evaluations over the central United States at the Climate Prediction Center. We will present information on the observational and model-based datasets, their availability and features, and also on the technique involved. The main water budget related parameters are atmospheric humidity and winds, atmospheric vapor flux convergence, tropospheric precipitable water, raingauge precipitation, river discharge, evaporation, subsurface/subsurface water storage and its rate of change

The results which are based on long-term monthly water budget components will include analyses and initialize discussions about:

- time series;
- mean annual cycles;
- mean annual variability;
- anomalies;
- long-term variations;
- accuracy and possible biases of estimates;
- impact of zonal and meridional components of the atmospheric vapor flux;
- relationship between stationary and transient components of the vapor flux;
- atmospheric vapor inflow/outflow through the boundaries of the area;
- differences between some water budget terms for northern and southern parts of the area;
- observations versus GCMs and mesoscale models;
- extreme events - how do we see them from different time series;
- vertical structure of moisture flux convergence.

Our presentations will include results of collaborative studies with other GCIP researchers (H. Berbery, E. Rasmusson - University of Maryland; P. Groisman - NCDC; K. Mitchell - NCEP; W. Higgins - CPC). Some of the results will be in their final form, other will be presented for the first time.

**MODEL PARAMETER ESTIMATION EXPERIMENT (MOPEX)**

John Schaake, Victor Koren, Quinyun Duan, Shuzheng Cong and Alan Hall
NWS Office of Hydrology

ABSTRACT

A key step in applying land surface parameterization schemes is to estimate model parameters that vary spatially and are unique to each grid point. It has been shown (e.g. in PILPS2c) that existing a priori parameter estimation techniques may produce large errors and biases in mean annual runoff. Improved methods for parameter estimation (especially for parameters important to runoff response) are needed. To develop these methods, data from a wide range of climate regimes throughout the world must be assembled, and an international cooperative effort to assess how well the different models can be estimated is required.

The primary goal of MOPEX is to assemble data sets that can be used by the scientific community to develop techniques for the a priori estimation of the parameters used in land surface parameterization schemes of atmospheric models and in hydrologic models. These parameter estimation schemes will be unique to each model and will relate model parameters to soils, vegetation, topographic and climatic characteristics.

An important step in achieving this goal is to assemble historical hydrometeorological data and river basin characteristics for about 200 intermediate scale river basins (500 - 10 000 km2) from a range of climates throughout the world. The data sets to be developed would not be model specific and would be appropriate for developing parameter estimation schemes for most, if not all, land surface parameterization schemes. These data will then be made available to the scientific community. The initial focus for MOPEX is to develop data sets from the Mississippi basin, make these available to the international scientific community, use these data to develop regionalized parameter estimation techniques, test the results, and encourage broad international collaboration in developing additional data sets and techniques for regionalized estimates of model parameters for different models.

The steps required are:

1. Develop historical hydrometeorological data sets (model forcing and output) and basin characteristics data (soils, vegetation, topography and climate).
2. Calibrate model parameters for a large number of basins (for a given model).
3. Relate calibrated model parameters to basin characteristics to develop regionalized apriori parameter estimation techniques for selected parameters (for a given model)
4. Use the regionalized parameter estimates for a large number of basins. Evaluate the results in terms of model performance when paramaters are estimated by:
    a. Initial a priori parameter estimation techniques
    b. Model calibration

    c. Regionalized a priori techniques derived using calibrated parameters
5. Test the transferability of the results to other basins not used in the above analysis. These basins may be in the same region or in other continents.
6. Expand the available data sets to include representation from all climate regimes of the earth and to achieve the best possible global coverage.
7. Assess whether parameters for some models are easier to estimate than parameters of others and modify models to have more "observable" parameters.
8. This poster presents an example of this approach to parameter estimation and reports on the progress to develop data sets for at least 50 basins.

**NOAA CORE PROJECT IN SUPPORT OF GCIP HYDROLOGIC MODELING, MODEL TESTING AND DATA PRODUCTS**

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ABSTRACT

The NOAA Core Project in support of GCIP is a collaborative effort involving the NWS National Environmental Modeling Center (NCEP), NESDIS and the NWS Office of Hydrology (OH). The NOAA GCIP Core Project has been designed to meet specific objectives under the GCIP operational path which are critical for GCIP and to provide essential support for other inter-related NOAA objectives which will in turn Benefit GCIP. The project prepares and transfers to the DMSS high quality, enhanced hydrologic and meteorological data sets that are not easily obtainable from sources other than the operational systems of OH and NCEP. The project is developing and has implemented physical enhancements to and expanded output products from 1) 4D Data Assimilation that will utilize new data products and 2) operational numerical weather prediction models (including those in 4D assimilation) by improving the land surface parameterization and coupling of atmospheric processes with surface hydrologic processes. Taking ideas from the research community, the projects serves to synthesize a wide range of incremental contributions to produce an improved Land Surface Sub-system (LSS) which will be used in all NCEP forecast models and which will be integrated into the National Weather Service River Forecast System (NWSRFS). Independent and collaborative tests of the current NCEP LSS are being undertaken in the context of PILPS2c and PILPS2d tests.

This poster presentation will provide an overview of a wide variety of accomplishments as part of the hydrology component during the past year and will summarize plans for the next year.

The accomplishments are in the following areas:

1. Data products supplied to GCIP DMSS
    a. Stage III merged gage/radar precipitation data
    b. RFC precipitation gage data
    c. Snow Products
2. LSS model component upgrades
    a. Frozen ground model
    b. Subsurface runoff component
    c. Areal snow accumulation and ablation model
3. Model testing and evaluation
    a. PILPS2c
    b. PILPS2d

4. Supporting data set development and off-line data analyses
    a. Hydraulic properties of soils analysis and data set development
    b. Historical hydrometeorological data analysis and data set development
    c. Drainage network connectivity data set development
    d. Analysis of potential evaporation estimates
    e. Off-line retrospective model simulations - reference data sets using alternative a priori parameter estimates
    f. Model scale dependency and basin segmentation studies
5. Collaboration with Hydrologic Research Laboratory (HRL) developement activities.

# USE OF NEXRAD WSR-88D RADAR OBSERVATIONS WITH RECLAMATION'S SNOW ACCUMULATION ALGORITHM FOR SNOW WATER EQUIVALENT ESTIMATION IN THE GCIP LSA-NC

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ABSTRACT

1. Range Correction For Reclamation'S Snow Accumulation Algorithm Reclamation will improve its NEXRAD WSR-88D Snow Accumulation Algorithm (SAA) by including a range correction scheme based on the vertical profile of equivalent reflectivity factor (Ze). Observations of Ze made by the Chanhassen, MN, WSR-88D throughout the 1996-97 winter are available as Level II taped copies. These data will be used to calculate the mean seasonal vertical profile of Ze in the lowest 3 km above the radar. The mean profile can be used to adjust SAA estimates of snow water equivalent (SWE) from the center of the lowest available beam tilt to the surface, for ranges beyond about 70 km. The SAA is known to underestimate SWE at mid- to far ranges, and the underestimation increases markedly beyond about 100 km. This underestimation is related to earth's curvature, beam spreading, and decreased likelihood of complete beam filling by snow particles at farther ranges.

   The mean vertical profile of Ze will be calculated for several snow storms. These mean storm profiles will be compared with the mean seasonal profile to provide an estimate of the uncertainty involved in using the latter to represent all storms.

   Plots of the mean vertical profile of Ze will be shown for selected Minnesota snow storms. It will be seen that Ze often increases as snow particles fall through the lowest 3 km. Since snow particles usually continue to grow to near-ground levels in at least the major storms, it might be anticipated that maximum Ze values would be observed near the ground.

2. Use Of Nids-Vendor Level Iii Reflectivity Data With Reclamation's Snow Accumulation Algorithm Reclamation's SAA currently uses 0.5 dBZ resolution Level II Ze observations for input. The SAA is being modified to run with the 4 to 5 dBZ resolution Level III Ze product intended for graphical displays in up to 16 levels (colors). Both Level II and Level III data have the basic range bin spatial resolution of 1 degree X 1 km. While the Level III product has degraded Ze resolution, it has the considerable advantage over Level II of being available in near real-time from NEXRAD Information Dissemination System (NIDS) vendors at affordable costs. Level II data are generally not available to non-NEXRAD agencies except as taped copies weeks after the fact. Moveover, the cost of Level II observations for an entire season of snow storms can be substantial.

The GCIP has archived Level III data from several LSA-NC WSR-88Ds during the 1996-97 winter, and plans to do so again during the 1997-98 winter. However, it has not been practical for the GCIP to archive Level II data which costs $100. per Exabyte tape copy. Therefore, a snow algorithm able to use Level III reflectivities could be used to estimate spatial SWE fields from Upper Midwest snow storms during last winter and the coming winter.

Examples of SAA SWE estimates will be shown for selected Minnesota snow storms based on both Level II and Level III data. These comparisons will show that the Level III product generally produces acceptable storm-total SWE estimates within about 75 km of the Chanhassen WSR-88D. Reasonable estimates to farther ranges are anticipated once the range correction scheme of 1. above is incorporated into the SAA.

# GOES SURFACE AND CLOUD PRODUCTS FOR VALIDATION OF REGIONAL NWP MODELS

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ABSTRACT

Beginning in late 1995 a set of hourly surface radiation, cloud and surface temperature products have been produced routinely in real time from the GOES-8 imager. Insolation from the GOES has been compared to coincident pyranometer data and the errors in the insolation are usually less than 10% of the insolation estimate. One of the purposes of the GOES products is to validate the radiation, cloud and surface parameterizations in regional NWP models, especially the NCEP Eta model. To do this a coincident Eta model/GOES data set is being constructed that merges selected variables from 3 hour Eta forecasts with coincident GOES estimates of the same quantities or of quantities that have been judged to be useful in comparing model and satellites quantities. The matchups are being done at 15, 18, 21, and 0Z which corresponds to mostly daylight hours over the GCIP area. Quantities in the matchup database include cloud fraction, insolation, surface (skin) temperature from both the Eta model and GOES. Other quantities include target mean and standard deviations of albedo and temperatures from the GOES and soil moisture, surface energy fluxes, vegetation fraction and snow water equivalent from the Eta. This data set will be made available to the GCIP science community.

## SCALES OF SOIL MOISTURE VARIABILITY AND REMOTE SENSING

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ABSTRACT

We have used soil moisture and meteorological observations from Illinois, USA, to estimate the scales of temporal and spatial variability in the soil moisture field. The temporal variability of soil moisture may be described as a red noise process with a scale of autocorrelation of about 2 months, and an added 10% of variance from very small scale variability that may be interpreted as a white noise component. According to the Delworth and Manabe (1988) theory this red noise component is a response of the land surface hydrological system to atmospheric forcing.

Spatial variability of the Illinois soil moisture field is a combination of white noise (30-35%) and red noise (65-70%), with a scale of spatial autocorrelation of about 380-490 km for the upper 10 cm of soil and of about 510-670 km for the upper 1 m soil layer. The estimated scale of spatial autocorrelation in the monthly precipitation field for Illinois is in the range 325-425km. It is similar to the scales of spatial variability of the soil moisture field.

We used in situ soil moisture data for Illinois and SMMR microwave measurements during 1982-1986 to evaluate the utility of using satellite passive microwave observations for retrieving soil moisture data. Only the long term and large scale components of soil moisture field variability, which are related to atmospheric forcing, may be retrieved from SMMR data. The polarization difference of brightness temperature at 18 GHz is found to be the best index for soil moisture of the upper 10 cm soil layer. We plan to test the same approach using SSM/I microwave data at 19 GHz and in other climatic regions. Existing soil moisture data for the Former Soviet Union, China, Mongolia and India will be used in future work on calibration of satellite microwave indices.

**THE GCIP IN-SITU DATA MODULE**

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ABSTRACT

The In-situ Module for the GCIP Data Management and Service System (DMSS) resides at the UCAR Joint Office for Science Support (JOSS). JOSS maintains an active page on the World Wide Web (WWW) providing links to various data centers and near real-time data sources, GCIP data plans and reports, information on GCIP CD-ROMS, other DMSS Modules, information on the GEWEX program, and related GCIP in-situ data links. Substantial data holdings are archived using the on-line JOSS data management system (CODIAC). CODIAC allows the user to browse, preview, subset, and order datasets on-line through dynamically generated WWW pages and forms.

This will be an electronic poster demonstrating the In-situ Module WWW pages and data access capabilities using the CODIAC system. Access to other DMSS Modules will also be available.

**DEVELOPMENT AND TESTING OF MACROSCALE HYDROLOGICAL MODELS FOR THE SOUTHERN PLAINS REGION OF GCIP: RESULTS FROM PILPS PHASE-2(C) RED-ARKANSAS RIVER EXPERIMENT**

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ABSTRACT

Sixteen land surface schemes participating in the Project for the Intercomparison of Land Surface Schemes(PILPS) phase-2(c) were run using ten-years (1979 - 1988) of forcing data for the Arkansas - Red River basins in the Southern Great Plains region of the United States. The basin have a combined area of 566,251 km2 which is represented by 61 1ocomputational grid boxes. The forcing data (precipitation, incoming radiation and surface meteorology) and land surface characteristics (soil and vegetation parameters) were provided. Three groups of runs were performed: (i) Calibration-validation runs, using data from six small catchments across the modeling domain, with the objective of testing the ability of the schemes to calibrate their parameters using data from smaller catchments and transferring this information to other basins and the computational grid boxes. (ii) Base-runs, using data for 1979 - 1988, aimed at evaluating the ability of current land surface schemes to reproduce measured energy and water fluxes over multiple seasonal cycles across a climatically diverse, continental-scale basin. And, (iii), sensitivity runs to determine which model parameters in the various schemes have the greatest affect on predicted surface fluxes. Observational data (from 1980-1986), which include daily river flows at gaging sites and monthly basin total evaporation, is used to evaluate the models. In general, the phase-2(c) base-run results are consistent with those reported from PILPS phase-1 and phase-2(a) experiments in terms of scatter in model-derived water and energy fluxes. The major results include:

For the energy balance, the mean annual net radiation varied between 80 and 105 Wm-2 among the models, except for the Bucket model (BUCK) that was anomalous (60 Wm-2). Its anomalous behavior appears to be related to its calculated high surface temperature. The mean annual Bowen ratio varied across the schemes from 0.52 to 1.73 (ignoring BUCK) which can be compared to the data-estimated regional mean annual Bowen ratio of 0.92. The sensible heat fluxes have larger differences among the schemes than the

latent heat flux, and the model-predicted ground heat fluxes have very large variations among models. There are larger differences among the models in the temporal (inter-annual) variability of surface fluxes and temperature than there are in the mean fields. Even for schemes with similar mean monthly latent, sensible, and ground heat flux fields, there were substantial differences in the inter-annual variability.

With regard to the estimation of runoff, the wide range of conceptualizations among the schemes for generation of surface and subsurface runoff resulted in significant differences that strongly affect the character of the resulting runoff hydrographs and in the ratio of surface runoff to drainage. Runoff ratios among the schemes varied from 0.02 to 0.41 and is compared to the observed runoff ratio for the basin of 0.15. Most schemes captured in their mean annual runoff the strong climatic east-west gradient of precipitation, and represented fairly well the spatial variability of runoff. But, most models predict too much runoff in the dry part of the basin. In estimating evapotranspiration, the seasonality was reproduced quite well but the mean monthly storage changes tend to be under estimated. All models tend to over-predict low evaporation periods (e.g. October) and under-predict high evapotranspiration periods (e.g., July and August).

Finally, the analysis of the calibration runs show that those schemes that did not calibrate parameters using data from the three calibration basins performed poorly on the validation basins and this poor performance carried over to their performance for the total modeling domain. Thus it appears that there is value in calibrating land surface schemes using catchment data even when the schemes are applied to larger computational grids.

# INVESTIGATION OF LAND SURFACE-US REGIONAL CLIMATE INTERACTIONS DURING SUMMER AND WINTER SEASONS

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ABSTRACT

Under the GCIP support, a coupled NCEP regional Eta model and a biosphere model SSiB have been used to study the impact of the land surface processes and parameterizations on the U.S. Summer weather prediction. The NCEP reanalyses data are used as initial conditions and lateral boundary conditions. The study has shown substantial improvement in simulations of precipitation and diurnal cycles of surface energy balance over the Mississippi River basin. However, thus far, these studies mainly focus on the summer season and short term (48 hour) weather forecast.

To develop the coupled model for regional climate study, the NCEP GCM has been coupled with the regional model to provide the lateral boundary conditions. Two extreme events, 1988 drought and 1993 flood, are simulated. The coupled global-regional model needs more spin up time than in our previous study when the reanalysis data was used for boundary conditions. However, overall, the coupled global-regional model still simulates the dry and wet events well and provide more information than by using the global model alone. The results using two different lateral conditions are compared and analyzed.

The winter season study has also been conducted. To more realistically simulate the impact of snow cover change, a multi-layer snow model has been developed to realistically simulate the heat and water transfer in a snow-cover surface. Several major physical and mechanical processes are considered, such as snow compaction process and the partitioning of the snow melting into runoff and infiltration. The numerical experiments have shown that three snow layers can produce the same accurate prediction as Jorden's (1991) fine layer model. The off-line snow model has been tested using Russian and French snow data. Meanwhile, the coupled Eta/SsiB model was tested for January 1996 (a heavy snow month) to investigate the major characteristics of land-atmosphere interaction in the winter season.